(54) Title: METHOD OF DETECTING RELATIVE POSITION OF EXPOSURE MASK AND OBJECT TO BE EXPOSED, ALIGNMENT METHOD, AND EXPOSURE METHOD USING THE SAME

MEMBRANE PORTION 101   PHOTOMASK SUPPORT 100
PHOTORESIST 300
WORKPIECE SUBSTRATE 301
STRUCTURE 106 TO BE USED IN SECOND-STAGE ALIGNMENT

A

B

C

D
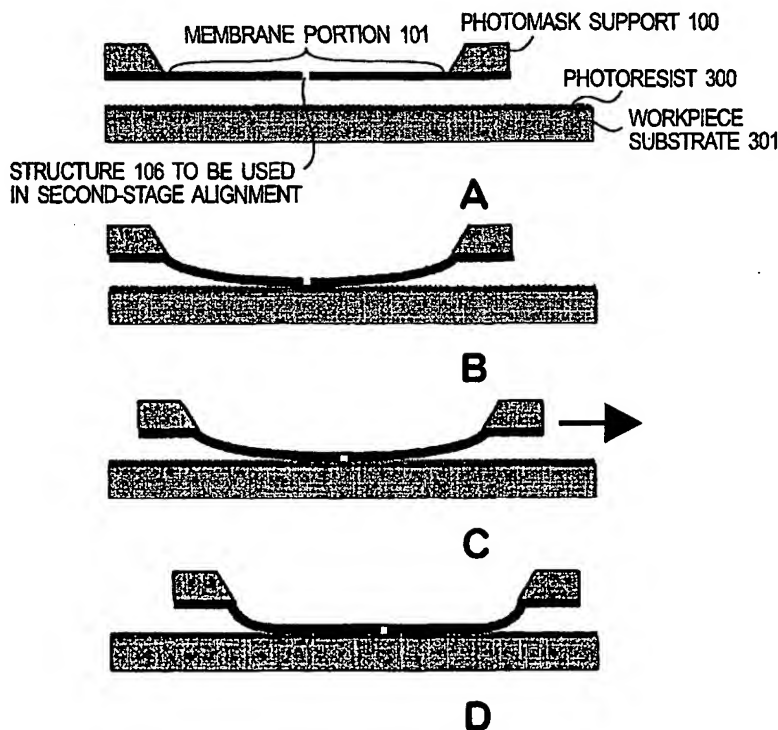
(57) Abstract: An alignment method for an exposure mask and an object to be exposed, wherein exposure is carried out while the exposure mask having a light blocking film formed at a membrane portion thereof is closely contacted to the object to be exposed and light from a light source is projected to the object to be exposed, through the exposure mask, and wherein alignment of the exposure mask and the object to be exposed is carried out prior to the exposure, the method comprising the steps of preparing an exposure mask having a light blocking film provided on a base material constituting the membrane portion and having a structure for performing position detection, flexing the membrane portion and detecting, by use of the structure, a relative position of the exposure mask and the object to be exposed, in a state in which the exposure mask is contacted to the object to be exposed, and aligning the exposure mask and the object to be exposed, with each other, on the basis of a result of the position detection.

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DESCRIPTION

METHOD OF DETECTING RELATIVE POSITION OF EXPOSURE
MASK AND OBJECT TO BE EXPOSED, ALIGNMENT METHOD,
AND EXPOSURE METHOD USING THE SAME

[TECHNICAL FIELD]

This invention relates to exposure
technology that enables manufacture of fine
patterns and, specifically, to a method of
detecting a relative position of an exposure mask
and an object to be exposed, an alignment method,
an exposure method using such alignment method, an
exposure mask, and an exposure apparatus having
such mask.

[BACKGROUND ART]

Because of continuing increases in
capacity of a semiconductor memory or in speed or
integration density of a CPU processor, further
advancements of microprocess based on optical
lithography are indispensable.

Generally, the limit of microprocess
using optical lithography apparatuses is of an
order of the wavelength of used light. For this
reason, the wavelengths of light used in optical
lithographic apparatuses have been shortened.

Currently, near-ultraviolet ray lasers are used,
and the microprocessing of 0.1 micron order is
enabled.

Although the minuteness attainable with
5   the optical lithography has advanced, in order to
accomplish microprocessing of an order of 0.1
micron or narrower, there still remain many
problems to be solved, such as the necessity of
shortening the laser wavelength further, or
10   developing lenses usable with such wavelength
region.

On the other hand, as a measure for
enabling optical microprocessing of an order of
0.1 micron or narrower, a microprocessing
15   apparatus using a structure of near-field optical
microscope, hereinafter "SNOM" (Scanning Near-
field Optical Microscope), has been proposed. An
example is an apparatus in which, by use of
evanescent light seeping or escaping from small
20   openings of a size not greater than 100 nm, local
exposure exceeding the limit of the wavelength of
light is carried out to a resist.

However, in lithographic apparatuses
using such SNOM structure, the microprocessing is
25   carried out on the basis of continuous drawing
using one probe (or a few probes). Thus, there is
a problem of low throughput.

As a measure for solving this problem,
U.S. Patent No. 6,171,730 discloses a method in
which a photomask is formed with a pattern
designed so that near-field seeps from between
5   light blocking films and the exposure is carried
out while the photomask is closely contacted to a
photoresist applied to a substrate, so that a fine
pattern of the photomask is transferred to the
resist at once.

10   The method and apparatus disclosed in
the specification of this patent is excellent, and
it makes a large contribution to the technical
field to which the present invention belongs.

            The near-field exposure method can
15 produce a fine pattern of an order of tens
nanometers, being much smaller than the wavelength
of light used for the exposure. For this reason,
in the aforementioned U.S. patent, the photomask
is provided with a membrane portion and, by
20 flexing it, the membrane portion is approximated
to a photoresist up to the near-field region, such
that the exposure is carried out in intimate
contact state.

            Here, if the alignment operation is
25 carried out while the membrane portion of the
photomask and the photoresist are spaced from each
other and if they are subsequently approximated to

each other up to the near-field region and the

exposure is carried out in such state, it may

cause a positional deviation of the near-field

exposure pattern, due to the flexure of the

5   membrane portion. Also, such positional deviation

may cause a decrease of the yield of device

production.

However, conventional reduction

projection system optical lithography or alignment

10   methods for X-ray exposure using a mask having a

membrane portion are basically an exposure method

in which, during the exposure process, the

photoresist and the photomask are exposed while

they are kept separated from each other. Thus, in

15   these methods, there is no suggestion for a

problem in a case in which, during the exposure

process, a photomask and a photoresist are exposed

while they are placed close to or in intimate

contact with each other. Therefore, these

20   conventional methods can not be directly applied

to an alignment method for the near-field exposure.

On the other hand, U.S. Patent No.

6,252,649 discloses an aligner comprising: an

aligner device for relatively moving and aligning

25   a mask having a pattern depicted thereon to be

exposed and an object having a photosensitive

layer to be subject to the exposure through said

mask; a contacting device for contacting said mask and said object as aligned; a detecting device for detecting the alignment accuracy of said mask and said object as contacted; separating means

5   responsive to said detecting device for separating said mask and said object from each other when the alignment accuracy of said contacted mask and object is detected by said detecting device to be out of a predetermined tolerance and in order to

10   align said mask and said object again; and an exposure apparatus for exposing said mask to said object as contacted with each other.

Additionally, the aforementioned U.S. Patent No. 6,252,649 shows a specific aligner in

15   which a pressure film is used to press a film-mask thereby to cause deformation of the film-mask. The pressure film is expanded to press the film-mask against the work to closely contact the former to the latter.

20   However, in the aligner apparatus disclosed in U.S. Patent No. 6,252,649, the pressure film and the film-mask are made separate such that there is a space between the pressure film and the film-mask. Thus, if a foreign

25   particle such as dust is present in such space, it may cause incomplete contact of the mask to the workpiece. Even if the close contact is complete,

the light projected from a light source would be influenced by the foreign particle, and accurate exposure would be prevented thereby.

5   [DISCLOSURE OF THE INVENTION]

The present invention provides a method and an apparatus by which the above-described problems can be solved.

The present invention provides a method

10   of detecting a relative position of an exposure mask and an object to be exposed, wherein exposure is carried out while the exposure mask having a light blocking film formed at a membrane portion thereof is closely contacted to the object to be

15   exposed and light from a light source is projected to the object to be exposed, through the exposure mask, and wherein the relative position of the exposure mask and the object to be exposed is to be detected prior to the exposure, characterized

20   by the steps of: preparing the exposure mask having a light blocking film provided on a base material constituting the membrane portion and having a structure for performing position detection; and flexing the membrane portion and

25   detecting, by use of the structure, a relative position of the exposure mask and the object to be exposed, in a state in which the exposure mask is

contacted to the object to be exposed.

The present invention provides an alignment method for an exposure mask and an object to be exposed, wherein exposure is carried out while the exposure mask having a light blocking film formed at a membrane portion thereof is closely contacted to the object to be exposed and light from a light source is projected to the object to be exposed, through the exposure mask, and wherein alignment of the exposure mask and the object to be exposed is to be carried out prior to the exposure, characterized by the steps of: preparing the exposure mask having a light blocking film provided on a base material constituting the membrane portion and having a structure for performing position detection; flexing the membrane portion and detecting, by use of the structure, a relative position of the exposure mask and the object to be exposed, in a state in which the exposure mask is contacted to the object to be exposed; and aligning the exposure mask and the object to be exposed, with each other, on the basis of a result of said position detection.

In accordance with the present invention, where a deviation with reference to a position to be exposed is detected by said

position detection, the flexure of the membrane
portion may be removed and the exposure mask and
the object to be exposed may be relatively moved
so as to remove the positional deviation, and
5   subsequently, the membrane portion may be flexed
again to be contacted to the object to be exposed
and, in that state, the position detection may be
carried out, wherein the above-described procedure
may be repeated once or more until the deviation
10 comes into a predetermined tolerable range for
exposure precision, whereby the alignment is
carried out.

In accordance with the present
invention, the structure for performing the
15 position detection may be formed adjacent a center
of the membrane or around the membrane.

The present invention provides an
exposure method, characterized by the steps of:
aligning an exposure mask and an object to be
20 exposed, by use of an alignment method of the
present invention; and performing exposure by
projecting light from a light source to the object
to be exposed, through the exposure mask, while
the exposure mask is closely contacted to the
25 object to be exposed.

The present invention provides an
exposure mask having a membrane portion including

a flexible structure, characterized in that a
light blocking film is provided on a base material
constituting the membrane portion, and that a
structure for performing alignment of the object
5   to be exposed and the exposure mask is provided at
a central portion of the membrane portion or
around the membrane portion.

     In the exposure mask according to the
present invention, the structure for performing
10   the alignment may be constituted by an opening
formed in said light blocking film.

     The present invention provides an
exposure apparatus, characterized by: an exposure
mask of the present invention; a pressure
15   adjusting device for causing flexure of a membrane
portion of the mask; a first driving device for
narrowing a distance between the mask and a
workpiece having an object to be exposed, applied
thereto; a second driving device for establishing
20   parallelism between a mask surface of the mask and
a surface of the object to be exposed; a position
detecting mechanism for detecting a position to be
exposed, by use of a structure for performing the
alignment; a third driving device for changing a
25   relative position of the mask and the workpiece
having the object to be exposed, on the basis of
information supplied from said position detecting

mechanism; and an exposure light source.

In accordance with the present invention, when an exposure mask having a membrane portion is closely contacted to a photoresist and

5   exposure is carried out, the position can be detected with smaller deviation with respect to the position to be detected. Thus, the present invention assures an alignment method, an exposure method using the alignment method, an exposure

10   mask, and an exposure apparatus having such mask, by which the yield of device production can be improved.

Particularly, in the present invention, the mask is provided with a light blocking film

15   formed on a base material constituting the membrane portion. Thus, the light blocking film and the membrane portion are formed integrally. Therefore, there is no possibility of dust or any other foreign particles entering between them, and

20   the above-described technical advantages are still assured.

These and other objects, features and advantages of the present invention will become more apparent upon a consideration of the

25   following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

[BRIEF DESCRIPTION OF THE DRAWINGS]

Figure 1 is a plane view of a photomask in an embodiment of the present invention, as seen from the entrance side of exposure light.

Figures 2A and 2B are sectional views, taken on line A-A', of the photomask in an embodiment of the present invention shown in Figure 1.

Figures 3A - 3D are views for explaining the procedure of near-field exposure method using a photomask of the structure shown in Figure 2A, in an embodiment of the present invention.

Figures 4A - 4D are views for explaining the procedure of exposure method in an embodiment of the present invention, in a case where breakage of a membrane, for example, is a problem to be considered.

Figures 5A - 5D are views for explaining the procedure of exposure method in an embodiment of the present invention, in a case where a structure to be used for the alignment is formed around the membrane.

Figure 6 is a sectional view of a photomask and a workpiece to be processed, in Example 1 of the present invention.

Figures 7A - 7E are views for
explaining the procedure optical nano-imprint
exposure method using a membrane mask in Example 3
of the present invention.

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[BEST MODE FOR PRACTICING THE INVENTION]

Figure 1 is a plane view of a photomask
in an embodiment of the present invention, as seen
from the entrance side of exposure light.

10   In Figure 1, the photomask comprises a
photomask support 100, a membrane portion 101
having a thickness of about 0.1 - 100 µm, and an
opening 102 to be used in first-stage alignment.
Additionally, while not shown in Figure 1, the

15   photomask further comprises a membrane base
material 103, a light blocking film 104, an
exposure pattern 105 formed at the back side of
the membrane portion, and a structure 106 to be
used in second-stage alignment.

20   Here, the opening 102 to be used for
the first-stage alignment is necessary only when
the first-stage alignment is to be performed. An
example is the exposure of a workpiece for
producing a structure in a first layer. If strict

25   positional precision is not required for the
workpiece, the first-stage alignment may be
omitted. In such case, as a matter of course, the

opening for use in the first-stage alignment is
unnecessary.

Figure 1 shows a case where there are
four membrane portions 101. However, a single
5   photomask may have membrane portions of any number.
From the standpoint of strength of the photomask,
the membrane portions may preferably be disposed
symmetrically with respect to the center of the
photomask.

10   As regards the shape of the membrane,
although a square shape is illustrated, it may
have any other shape. From easiness of process,
an oblong shape is good, but where tensile stress
or distortion of the membrane as it is flexed are
15   taken into account, the square shape is preferable
than the oblong shape. Also, while the easiness
of process may be inferior, a regular polygon
having vertices of a number larger than that of
the square shape is preferable.

20   Although the photomask support 100
illustrated has a rectangular shape, it may have
any other shape, such as a circular shape, for
example. From the standpoint of performing
initial alignment prior to the first-stage
25   alignment, a rectangular or even a circular shape
with an orientation flat is preferable, because
the orientation can be detected easily.

As regards the opening 102 to be used for the first-stage alignment, the illustrated example uses two cross-shaped openings. The presence/absence, disposition, number and shape of

5   the openings may be different in accordance with the necessity of the first-stage alignment and the required precision thereof.

Figure 2 shows the section, along a line A-A', of the photomask shown in Figure 1. In

10   Figure 2, denoted at C is the center of the photomask. Also, Figure 2 illustrates an opening defined by processing the light blocking film 104, as an example of the structure 106 to be used in the second-stage alignment.

15   As regards the alignment method for the second stage, various methods are usable such as, for example, a method in which light of low sensitivity to the workpiece is projected through use of an opening and the quantity of reflected

20   light from the structure formed on the workpiece is detected, or an image is provided by reflected light. Alternatively, the quantity or intensity of light emission from a fluorescent substance provided on the workpiece may be detected.

25   As regards the structure for use in the alignment, in place of the opening, an STM (scanning tunnel microscope) probe structure may

be used and, in that occasion, the shape of a

structure formed on the workpiece can be detected.

The exposure pattern 105 shown in

Figure 2 is merely an example. This pattern is

5   variable arbitrarily in accordance with what is

required for the product. Specifically, Figure 2A

shows a case wherein the structure 106 to be used

for the second-stage alignment is formed adjacent

the center of the membrane portion 101. Figure 2B

10   shows a case wherein the structure 106 is formed

around the membrane portion 101.

Referring to Figure 3, the near-field

exposure method using a photomask of the structure

shown in Figure 2A, will be explained.

15   First of all, the photomask having a

structure to be used in the second-stage alignment,

formed adjacent the center of the membrane portion   o

101, is disposed so that its light blocking film

is opposed to a photoresist 300 formed on the

20   workpiece 301, the photoresist being the object to

be exposed (Figure 3A). Here, as regards the

distance between the light blocking film surface

and the photoresist surface, although it depends

on the area of the membrane portion, from the

25   standpoint of the durability of the membrane

portion, the distance should be not greater than

100 µm and they should be placed close to each

other unless the membrane portion and the
photoresist surface do not contact with each other.
     Subsequently, by decreasing the
pressure between the membrane portion 101 and the
5 photoresist 300 or, alternatively, by pressurizing
the membrane 101 from the mask support 100 side,
the membrane 101 is flexed until only the central
portion thereof contacts the photoresist 300
(Figure 3B).

10   Then, position detection is carried out
by using the structure 106 (alignment marker) to
be used in the second-stage alignment formed
adjacent the center of the membrane portion 101 as
well as an alignment marker structure provided on
15 the workpiece 301. If a deviation between this
position and the position to be exposed is within
a tolerable range for the required exposure
precision, the photomask is further flexed so that
the whole surface of the exposure pattern is
20 closely contacted to the photoresist 300.
Thereafter, the exposure is carried out.

     If the deviation is beyond the
tolerable range for the required exposure
precision, the relative position of the photomask
25 and the workpiece is shifted in a direction of an
arrow, being parallel to the opposed surfaces of
them, while the central portion of the membrane

and the photoresist are kept in contact with each
other, and they are brought into alignment with
each other so that the positional deviation comes
into the tolerable range (Figure 3C).

5   After this, the photomask is flexed
furthermore and the whole surface of the exposure
pattern is closely contacted to the photoresist.
Then, exposure light is projected to the membrane
from the photomask support side, and exposure is

10   carried out (Figure 3D).

With this arrangement, the exposure can
be accomplished while the positional deviation
between prior to flexing the membrane portion and
at the time of exposure where the membrane is

15   flexed is removed. Therefore, the positional
deviation of the pattern can be made small, and
the yield of device production can be improved.

Where relatively moving the central
portion of the membrane and the photoresist while

20   they are kept in contact with each other may cause
a problem such as breakage of the membrane,
shortening the lifetime of the membrane, roughing
the photoresist surface (it may cause a problem in
a post-process), for example, the procedure shown

25   in Figure 4 may be used.

What differs from the above-described
procedure is as follows. The position detection

is carried out by using structures (alignment
marker structures) for use in the second-stage
alignment, provided on the workpiece 301 and the
membrane portion 101. If the deviation between
5   this position and the position to be exposed is
out of the tolerable range for the required
exposure precision, first the flexure of the
membrane portion is removed to separate the
membrane and the photoresist from each other.
10   After this, the relative position of the photomask
and the workpiece is moved in a direction of an
arrow, being parallel to the opposed surfaces of
them, so that they are brought into alignment
(Figure 4C).
15   Subsequently, the membrane portion is
flexed again to the extent that only the central
portion of the membrane contacts the photoresist,
and then the position detection is carried out.
If a deviation between this position and the
20   position to be exposed is within a tolerable range
for the required exposure precision, the photomask
is further flexed so that the whole surface of the
exposure pattern is closely contacted to the
photoresist 300. Thereafter, the exposure is
25   carried out (Figure 4D).
             If the deviation is beyond the
tolerable range for the required exposure

precision, even after completion of the
translational motion (Figure 4C), the above-
described procedure, that is, the operation of
Figures 4B and 4C, is repeated.

5   If the deviation between this position
and the position to be exposed comes into a
tolerable range for the required exposure
precision, the photomask is further flexed so that
the whole surface of the exposure pattern is

10   closely contacted to the photoresist 300.
Thereafter, by projecting exposure light to the
membrane from the mask support side, the exposure
is carried out (Figure 4D).

          With this arrangement, the exposure can

15   be accomplished while the positional deviation
between prior to flexing the membrane portion and
at the time of exposure where the membrane is
flexed is removed. Therefore, the positional
deviation of the pattern can be made small, and

20   the yield of device production can be improved.

          Furthermore, since a force to be
applied to the central portion of the membrane or
to a photoresist that contacts to the central
portion of the membrane is reduced, the lifetime

25   of the photomask can be prolonged and
deterioration of the resist pattern can be
prevented.

If the structure (alignment marker
structure) to be used in the second-stage
alignment can not be formed adjacent the membrane
center, for some reason related to the exposure
5   pattern, such structure may be provided around the
membrane as in the photomask shown in Figure 2B.

Referring to Figure 5, the near-field
exposure method using a photomask of the structure
shown in Figure 2B, will be explained.

10   First of all, a photomask having a
structure 106 (alignment marker structure) to be
used in the second-stage alignment, formed around
the membrane portion 101, is disposed so that,
like the example of Figure 3, its light blocking
15   film is opposed to a photoresist 300 formed on the
workpiece 301, the photoresist being the object to
be exposed (Figure 5A).

Subsequently, the membrane portion 101
is flexed until the portion having the structure
20   106 is contacted to the photoresist 300 (Figure
5B).

Then, position detection is carried out
by using the structure (alignment marker
structure), to be used in the second-stage
25   alignment, provided on the membrane portion 101
and the workpiece 301. If a deviation between
this position and the position to be exposed is

within a tolerable range for the required exposure
precision, the photomask is further flexed so that
the whole surface of the exposure pattern is
closely contacted to the photoresist 300.

5   Thereafter, the exposure is carried out.

Here, a plurality of alignment marker
structures for use in the alignment may be
provided at symmetrical positions about the
membrane center, and in that occasion, the

10   positional deviation can be detected from an
average of the positions detected by these
structures. This improves the precision much more,
and it is particularly effective to the correction
of positional deviation caused as a result of

15   flexing the membrane.

If the deviation is beyond the
tolerable range for the required exposure
precision, the relative position of the photomask
and the workpiece is shifted in a direction of an

20   arrow, being parallel to the opposed surfaces of
them, and they are brought into alignment with
each other so that the positional deviation comes
into the tolerable range. After this, the
photomask is flexed furthermore and the whole

25   surface of the exposure pattern is closely
contacted to the photoresist 300. Then, exposure
light is projected to the membrane from the

photomask support side, and exposure is carried
out (although not shown in the drawings).

If relatively moving the central
portion of the membrane and the photoresist while
5   they are kept in contact with each other may cause
a problem such as breakage of the membrane,
reduction in lifetime of the membrane, roughing of
the photoresist surface (resulting in a problem in
a post-process), for example, the flexure of the
10   membrane portion may be removed and, after this,
the relative position of the photomask and the
workpiece may be moved in parallel to the opposed
surfaces of them (Figure 5C).

If the deviation is beyond the
15   tolerable range for the required exposure
precision, even after completion of the
translational motion, the above-described
procedure is repeated until the deviation comes
within the tolerable range for the required
20   exposure precision, like the case of Figure 4
(Figure 5D).

With this arrangement, even if the
structure to be used in the second-stage alignment
can not be formed adjacent the membrane center,
25   for some reason related to the exposure pattern,
the exposure can be accomplished while the
positional deviation between prior to flexing the

membrane portion and at the time of exposure where

the membrane is flexed is removed. Therefore, the

positional deviation of the pattern can be made

small, and the yield of device production can be

5   improved.

Furthermore, when the relative position

of the photomask and the workpiece is to be

changed, the flexure of the membrane portion is

removed and the membrane is separated from the

10   photoresist. As a result, a force to be applied

to the central portion of the membrane or to a

photoresist that contacts to the central portion

of the membrane is reduced. Therefore, the

lifetime of the photomask can be prolonged and

15   deterioration of the resist pattern can be

prevented.

In an alignment method according to the

present invention, if the peripheral portion of

the membrane mask is supported by a rigid

20   supporting member such as shown in Figure 1,

deformation of the membrane responsive to pressure

application is such that the membrane center

shifts in a direction of a normal to the membrane

surface. Such deformation is similar to

25   deformation of a beam being supported at its

opposite ends, and it shows excellent parallelism

in the normal direction as well as a good

reproducibility. Thus, it provides an advantage
of higher precision alignment.

Regarding the alignment method, while
the near-field exposure method has been explained
5   as an example, the present invention is not
limited to this. The present invention is
applicable also to any other exposure method such
as, for example, an optical nano-imprint exposure
method in which a membrane mask is flexed.

10   Next, some examples of the present
invention will be explained.

[Example 1]

Figure 6 is a schematic view of a
15   portion of a photomask and a workpiece used in
this example.

As regards the photomask support, Si
substrate 600 was used. On this Si substrate 600,
SiN film 601 as membrane base material was formed
20   with a film thickness of 300 nm. On this film, Cr
film 602 which functions as a light blocking film
for the exposure light was formed by vapor
deposition, with a film thickness of 50 nm. By
processing the Cr film 602 by use of an FIB
25   (focusing ion beam) processing machine, an
exposure pattern 105 (an original pattern for
exposure of the photoresist) and an opening 605 to

be used in the second-stage alignment were
produced in a portion of the Cr film 602. The
exposure pattern 105 includes a fine pattern
having a smallest linewidth of 50 nm.

5   Thereafter, back-etching of the Si
substrate 600 was carried out relative to the SiN
film 601, from the side of the photomask remote
from its Cr film 602 portion, whereby the membrane
portion 101 was formed. During the back-etching

10   of the Si substrate 600, the openings (not shown)
to be used in the first-stage alignment were also   .
made.

In this example, in regard to a Si
pattern 606 formed upon an insulative film 607 on

15   a Si substrate 608, SOI substrate having a fine
metal pattern formed thereon was used as a
workpiece substrate. On this workpiece substrate,
a lower-layer thick resist 604 was formed by spin
coating, with a film thickness 200 nm. Then, it

20   was heated in an oven at 200 °C for one hour.
Thereafter, a Si containing resist 603 for g-line
exposure was applied to a film thickness of 50 nm,
and pre-baking was performed by using a hot plate,
at 90 °C for 90 seconds.

25   The Cr film side (light blocking film)
of the photomask and the Si containing resist 603
side of the SOI substrate were disposed opposed to

each other. The photomask was held by fixing the Si substrate 600 (supporting portion) by use of a vacuum chuck. Regarding the SOI substrate, the Si substrate 608 was fixed on a stage. In such state,

5   the light blocking film surface (Cr film 602) and the Si containing resist 603 surface were approximated to each other so that the interval between them became equal to 50 μm.

In such state, the opening to be used

10 in the first-stage alignment was used, and yellow light provided by cutting short wavelengths in white light, having high exposure sensitivity to the Si containing resist, was used to perform the alignment, whereby rough alignment of the

15 photomask and the workpiece opposed to it was carried out.

Subsequently, a pump was used to pressurize the membrane portion 101 from the Si substrate 600 side, to cause flexure of the

20 membrane portion 101. Simultaneously, similar yellow light as described above was used, and while observing interference fringe produced on the membrane from the photomask supporting member side, only the Cr film adjacent the opening 605

25 was brought into contact with the Si containing resist 603. In such state, through the opening 605 formed adjacent the center of the membrane

portion 101, light of a wavelength having low

exposure sensitivity to the Si containing

photoresist 603 was projected, and the intensity

of reflected light from the Si pattern 606 was

5   detected by a detector. Based on this, a relative

positional deviation between the photomask and the

workpiece is detected. Since this example used Si

containing resist for g-line exposure light, a red

laser of a wavelength 635 nm was used to perform

10   the position detection, and a positional deviation

of 0.7 μm was found with respect to the alignment

marker on the SOI substrate.

        The positional deviation was removed by

moving a stage on the SOI substrate side, and

15   thereafter, by pressuring the membrane until the

whole surface of the exposure pattern in the

membrane closely contacted to the Si containing

resist 603, whereby the membrane 101 was flexed.

In such state, light from an Hg lamp was projected

20   to the whole surface of the photomask from the Si

substrate 600 side, whereby the exposure was

carried out.

        Subsequently, by developing the Si

containing resist 603, a pattern of the Si

25   containing resist 603 was produced. By using it

as a mask and by using an oxygen gas, dry etching

was carried out to the lower-layer thick resist

604, whereby a resist pattern was produced.
Thereafter, metal was applied by vapor deposition
and, then, the resist was removed. With this
procedure, a fine metal pattern having a small

5   positional deviation with respect to the Si
pattern 606 on the insulating film 607 can be
produced. Therefore, the yield of device
production can be improved.

10   [Example 2]

In this embodiment, the procedure up to
the position detection using the opening 605 is
the same as Example 1, and description thereof
will be omitted.

15   Like Example 1 described above,
position detection was carried out by use of red
laser of a wavelength 635 nm, and it was found a
positional deviation of 0.7 μm with respect to an
alignment marker on the SOI substrate.

20   Here, by using a pump, the membrane
portion 101 was depressurized from the Si
substrate 600 side to reduce the flexure of the
membrane portion 101, so that the membrane portion
101 was disengaged from the Si containing resist

25   603. Also, it can be checked by observing
interference fringe produced at the membrane, by
use of yellow light and from the photomask

supporting member side.

Thereafter, the stage at the SOI substrate side was moved to remove the positional deviation, and then the membrane was pressurized

5   until the whole surface of the exposure pattern of the membrane was closely contacted to the Si containing resist 603, whereby the membrane portion 101 was flexed. In such state, light from an Hg lamp was projected to the whole surface of

10 the photomask from the Si substrate 600 side, and exposure was carried out. The procedure following this is similar to that of Example 1.

With the exposure process according to the method described above, a fine metal pattern

15 having a small positional deviation with respect to the Si pattern 606 on the insulating film 607 was produced. Further, the membrane breakage frequency was reduced and the pattern shape of the Si containing resist after the development was

20 improved. Thus, the yield of device production was improved significantly.

[Example 3]

Referring to Figure 7, an example

25 wherein the present invention is applied to an optical nano-imprint exposure method in which a membrane mask is flexed, will be described.

As shown in Figure 7A, a mask is
constituted by a membrane 701 of a thickness of
0.1 - 100 μm, and it has an irregularity
(inequality) structure 702 formed at its front

5   face. The alignment method in such optical nano-
imprint exposure method using such mask will be
performed in the following manner.

First of all, a membrane mask having a
mask side marker structure 705, to be used in fine

10   alignment to be performed after rough alignment,
formed adjacent the center of the membrane 701, is
disposed so that its front face is opposed to an
ultraviolet-ray setting resin liquid 704 (object
to be exposed) provided on a workpiece 703 (Figure

15   7A).

Subsequently, by depressurizing the
space between the membrane 701 portion and the
ultraviolet-ray setting resin liquid 704 or by
pressurizing the membrane 701 portion from the

20   back side of the membrane mask supporting member
706, the membrane 701 portion is brought into
contact, from its central portion, with the
ultraviolet-ray setting resin liquid 704. Thus,
the membrane is flexed so that the inequality

25   structure 702 at the membrane mask surface sink
into the ultraviolet-ray setting resin liquid 704
(Figure 7B).

Then, position detection is carried out
by using a mask-side marker structure 705 to be
used in the fine alignment, formed adjacent the
center of the membrane 701 portion as well as a
5   substrate-side marker structure ·707. If a
deviation between this position and the position
to be exposed is within a tolerable range for the
required exposure precision, (as will be described
with reference to Figures 7D and 7E) the membrane
10   mask is further flexed so that the whole surface
of the inequality structure pattern 702 sinks into
and is intimately contacted to the ultraviolet-ray
setting resin liquid 704, till a portion adjacent
the surface of the workpiece 703. Thereafter,
15   ultraviolet light is projected to set the resin
liquid 704.

If the deviation is beyond the
tolerable range for the required exposure
precision, the relative position of the membrane
20   mask 701 and the workpiece 703 is shifted in a
direction of an arrow, being parallel to the
opposed surfaces of them, while the central
portion of the membrane 701 and the ultraviolet-
ray setting resin liquid 704 are kept in contact
25   with each other, and thus alignment is carried out
(Figure 7C).

After this, the membrane mask is flexed

furthermore and the whole surface of the

inequality structure 702 pattern is sank into the

ultraviolet-ray setting resin liquid 704, up to a

portion adjacent the surface of the workpiece 703

5   (Figure 7D). Thereafter, the ultraviolet light is

projected to set the resin liquid 704 (Figure 7E).

With this arrangement, the exposure can

be accomplished while the positional deviation

between prior to flexing the membrane portion and

10   at the time of exposure where the membrane is

flexed is removed. Therefore, the positional

deviation of the pattern can be made small, and

the yield of device production can be improved.

15

CLAIMS

1.   In a method of detecting a relative
position of an exposure mask and an object to be
5   exposed, wherein exposure is carried out while the
exposure mask having a light blocking film formed
at a membrane portion thereof is closely contacted
to the object to be exposed and light from a light
source is projected to the object to be exposed,
10   through the exposure mask, and wherein the
relative position of the exposure mask and the
object to be exposed is to be detected prior to
the exposure, characterized by the steps of:
          preparing the exposure mask having a
15   light blocking film provided on a base material
constituting the membrane portion and having a
structure for performing position detection; and
          flexing the membrane portion and
detecting, by use of the structure, a relative
20   position of the exposure mask and the object to be
exposed, in a state in which the exposure mask is
contacted to the object to be exposed.

2.   In an alignment method for an exposure
25   mask and an object to be exposed, wherein exposure
is carried out while the exposure mask having a
light blocking film formed at a membrane portion

thereof is closely contacted to the object to be

exposed and light from a light source is projected

to the object to be exposed, through the exposure

mask, and wherein alignment of the exposure mask

5   and the object to be exposed is to be carried out

prior to the exposure, characterized by the steps

of:

preparing the exposure mask having a

light blocking film provided on a base material

10   constituting the membrane portion and having a

structure for performing position detection;

flexing the membrane portion and

detecting, by use of the structure, a relative

position of the exposure mask and the object to be

15   exposed, in a state in which the exposure mask is

contacted to the object to be exposed; and

aligning the exposure mask and the

object to be exposed, with each other, on the

basis of a result of said position detection.

20

3.   An alignment method according to Claim

2, wherein, where a deviation with reference to a

position to be exposed is detected by said

position detection, the flexure of the membrane

25   portion is removed and the exposure mask and the

object to be exposed are relatively moved so as to

remove the positional deviation, and subsequently,

the membrane portion is flexed again to be
contacted to the object to be exposed and, in that
state, the position detection is carried out, and
wherein the above-described procedure is repeated
5   once or more until the deviation comes into a
predetermined tolerable range for exposure
precision, whereby the alignment is carried out.

        4.   An alignment method according to Claim
10   2, wherein the structure for performing the
position detection is formed adjacent a center of
the membrane or around the membrane.

        5.   An exposure method, characterized by
15   the steps of:
        aligning an exposure mask and an object
to be exposed, by use of an alignment method as
recited in Claim 2; and
        performing exposure by projecting light
20   from a light source to the object to be exposed,
through the exposure mask, while the exposure mask
is closely contacted to the object to be exposed.

        6.   An exposure mask having a membrane
25   portion including a flexible structure,
characterized in that a light blocking film is
provided on a base material constituting the

membrane portion, and that a structure for

performing alignment of the object to be exposed

and the exposure mask is provided at a central

portion of the membrane portion or around the

5 membrane portion.

       7.   An exposure mask according to Claim 6,

wherein the structure for performing the alignment

is constituted by an opening formed in said light

10 blocking film.

       8.   An exposure apparatus, characterized

by:

            an exposure mask as recited in Claim 6;

15   a pressure adjusting device for causing

flexure of a membrane portion of the mask;

            a first driving device for narrowing a

distance between the mask and a workpiece having

an object to be exposed, applied thereto;

20   a second driving device for

establishing parallelism between a mask surface of

the mask and a surface of the object to be

exposed;

            a position detecting mechanism for

25 detecting a position to be exposed, by use of a

structure for performing the alignment;

            a third driving device for changing a

relative position of the mask and the workpiece

having the object to be exposed, on the basis of

information supplied from said position detecting

mechanism; and

5   an exposure light source.

PHOTOMASK SUPPORT 100

MEMBRANE PORTION 101

OPENING 102 TO BE USED
IN FIRST-STAGE ALIGNMENT

FIG.1

PHOTOMASK SUPPORT 100   MEMBRANE PORTION 101   MEMBRANE BASE MATERIAL 103

LIGHT BLOCKING FILM 104

EXPOSURE PATTERN 105   STRUCTURE 106 TO BE USED IN SECOND-STAGE ALIGNMENT

FIG.2A

STRUCTURE 106 TO BE USED IN SECOND-STAGE ALIGNMENT   EXPOSURE PATTERN 105

FIG.2B

MEMBRANE PORTION 101   PHOTOMASK SUPPORT 100

PHOTORESIST 300

WORKPIECE
SUBSTRATE 301

STRUCTURE 106 TO BE USED
IN SECOND-STAGE ALIGNMENT

FIG.3A

FIG.3B

FIG.3C

FIG.3D

FIG.4A

FIG.4B

FIG.4C

FIG.4D

FIG.5A

STRUCTURE 106 TO BE USED IN SECOND-STAGE ALIGNMENT

FIG.5B

FIG.5C

FIG.5D

SI SUBSTRATE 600   OPENING 605
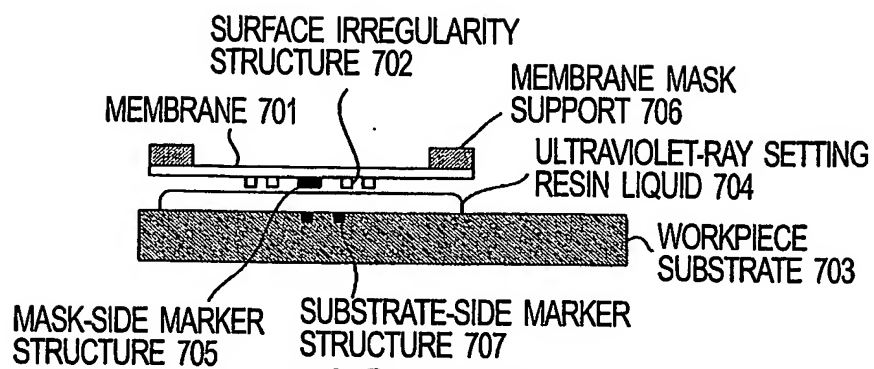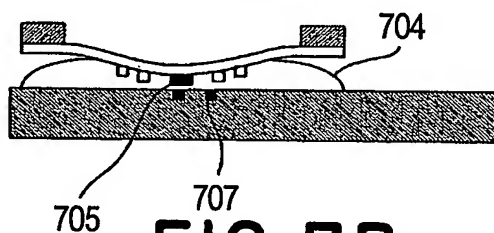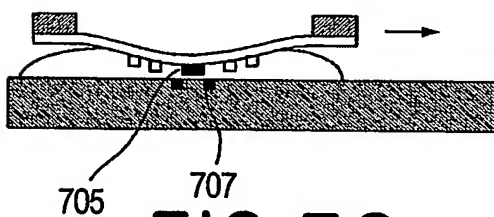
MEMBRANE PORTION 101   SiN FILM 601

Cr FILM 602

EXPOSURE PATTERN 105 Si PATTERN 606 Si-CONTAINING RESIST 603

LOWER-LAYER THICK RESIST 604

INSULATING FILM 607

Si-SUBSTRATE 608

FIG.6

SURFACE IRREGULARITY
STRUCTURE 702

MEMBRANE MASK
SUPPORT 706

MEMBRANE 701

ULTRAVIOLET-RAY SETTING
RESIN LIQUID 704

WORKPIECE
SUBSTRATE 703

MASK-SIDE MARKER
STRUCTURE 705

SUBSTRATE-SIDE MARKER
STRUCTURE 707

FIG.7A

704

705 707

FIG.7B

705 707

FIG.7C

FIG.7D

FIG.7E